U.S. NUCLEAR REGULATORY COMMISSION

STANDARD REVIEW PLAN

OFFICE OF NUCLEAR REACTOR REGULATION

7.2 REACTOR TRIP SYSTEM

REVIEW RESPONSIBILITIES

Primary - Instrumentation and Control Systems Branch (ICSB)

Secondary - None

I. AREAS OF REVIEW

This SRP section describes the review of the reactor trip system (RTS), which is part of the reactor protection system, and includes those power sources, sensors, initiation circuits, logic matrices, bypasses, interlocks, racks, panels and control boards, and actuation and actuated devices, that are required to initiate reactor shutdown. The RTS is designed to initiate automatically the reactivity control system (control rods), to assure that specified acceptable fuel design limits are not exceeded. The review of the controls, inhibits, and interlocks for the withdrawal, insertion, and sequence of control rods is included in Section 7.7 of the safety analysis report (SAR).

The objectives of the review are to confirm that the RTS satisfies the requirements of the acceptance criteria and guidelines applicable to the protection system and will perform its safety function during all plant conditions for which they are required.

The review performed for a construction permit application may be based on preliminary designs and the depth of information need only be sufficient to provide reasonable assurance that the final design will conform to the design bases and applicable criteria with an adequate margin for safety. The review performed for an operating license (OL) application is based upon detailed design information that confirms that the final design conforms to the design bases and applicable criteria. The depth of the review for an OL application should be sufficient to conclude that the requirements of the Commission regulations have been satisfied. The depth of the review for the balance of the criteria applicable to the protection system should be sufficient to conclude that the systems conform with the guidelines to the extent required to support the findings of conformance to the regulations.

USNRC STANDARD REVIEW PLAN

Standard review plans are prepared for the guidance of the Office of Nuclear Reactor Regulation staff responsible for the review of applications to construct and operate nuclear power plants. These documents are made available to the public as part of the Commission's policy to inform the nuclear industry and the general public of regulatory procedures and policies. Standard review plans are not substitutes for regulatory guides or the Commission's regulations and compliance with them is not required. The standard review plan sections are keyed to the Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants. Not all sections of the Standard Format have a corresponding review plan.

Published standard review plans will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience.

Comments and suggestions for improvement will be considered and should be sent to the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Washington, D.C. 20555.

The scope of the ICSB review of Section 7.2 of an SAR includes:

1. The descriptive information, including functional control diagrams (CP) and schematic diagrams (OL) pertaining to the RTS. The RTS includes all electrical and electromechanical equipment involved in detecting a plant condition requiring and in initiating a reactor trip.

2. The acceptance criteria, guidelines, and design bases used for the design of the RTS (CP).

3. The applicant's analysis of the conformance to the acceptance criteria, guidelines, and design bases for the RTS (OL).

In addition, the ICSB will coordinate with other branches that interface with the overall review of the following aspects of RTS:

1. The adequacy of the monitored variables, i.e., the suitability of parameters, such as pressure, for initiating a reactor trip.

2. The acceptability of the proposed trip setpoints, time delays, accuracy requirements, and actuated equipment response consistent with the safety analysis included in Chapter 15 of the SAR.

The coordinated reviews include the following:

The Power Systems Branch (PSB) evaluates the adequacy of physical separation criteria for cabling and electrical power equipment and determines that control and motive power supplied to redundant systems is from appropriate redundant sources as part of its primary review responsibility for SRP Sections 8.2, 8.3.1 and 8.3.2.

The Auxiliary Systems Branch (ASB) evaluates the adequacy of the essential auxiliary support (EAS) systems to assure these systems satisfy the applicable acceptance criteria as part of its primary review responsibility for SRP Chapter 9 and 10. This review confirms that the design of the EAS systems is compatible with the single failure requirements of the RTS to perform its acquired safety functions and that the EAS systems that are essential to RTS operation will adequately maintain the required environmental condition in areas where RTS equipment is located.

The Reactor Systems Branch (RSB) evaluates the adequacy of protective functions consistent with the accident analysis as part of its primary review responsibility for SRP Chapter 15.

The Core Performance Branch (CPB) reviews the reactivity control aspects of the RTS, including the placement of neutron sensors with regard to measurement of the flux spatial dependence, the flux magnitude, and calibration effects of all operating modes throughout core life as part of its primary review responsibility for SRP Section 4.3.

The Equipment Qualification Branch (EQB) reviews the seismic and environmental qualification of instrumentation and electrical systems as part of its primary review responsibility for SRP Sections 3.10 and 3.11. This review includes the design criteria and testing methods employed in the seismic design and installation of Category Instrumentation and Control equipment.

For those areas of review identified above as being reviewed as part of the primary review responsibility of other branches, the acceptance criteria necessary for the review and their methods of application are contained in the referenced SRP sections of the corresponding primary branch.

II. ACCEPTANCE CRITERIA

The acceptance criteria and guidelines applicable to the RTS are identified in SRP Section 7.1. The review of Section 7.1 of the SAR confirms that the appropriate acceptance criteria and guidelines have been identified as applicable for this system. The review of the RTS in this section of the SAR confirms that this system conforms to the requirements of the acceptance criteria and guidelines. The branch technical positions are used when a particular design problem and an acceptable solution have been identified.

Acceptance criteria for the review of the RTS are based on melting the relevant requirements of the following regulations:

1. 10 CFR Part 50, §50.55a(h), "Codes and Standards" - IEEE Std 279, "Criteria for Protection Systems for Nuclear Power Generating Stations."

2. General Design Criteria 2, "Design Basis for Protection Against Natural Phenomena."

3. General Design Criterion 4, "Environmental and Missile Design Basis."

4. General Design Criterion 20, "Protection Systems Functions."

5. General Design Criterion 21, "Protection System Reliability and Testability."

6. General Design Criterion 22, "Protective System Independence."

7. General Design Criterion 23, "Protection System Failure Modes."

8. General Design Criterion 24, "Separation of Protection and Control Systems."

9. General Design Criterion 25, "Protection System Requirements for Reactivity Control Malfunctions."

Regulatory Guides, Branch Technical Positions and industry standards that provide information, recommendations and guidance and in general describe a basis acceptable to the staff that may be used to implement the relevant requirements of the Commission Regulations identified above are given in SRP Section 7.1, Table 7-1 (Ref. 1) and SRP Appendix 7-A (Ref. 2). In addition, Task Action Plan items are also implemented to meet the above regulations as identified in SRP Section 7.1, Table 7-2 (Ref. 3).

III. REVIEW PROCEDURES

This subsection describes the general procedures to be followed in reviewing the RTS. The bases for the evaluation of conformance to the requirements of the acceptance criteria and guidelines may be based upon referenced approved designs. The category of referenced approved designs include topical reports, standard design approvals, and designs of systems which have been reviewed and

approved by the Staff. If any aspect of a design is not identical to that which is referenced, an evaluation must be made to address the adequacy of the differences and the conclusions included in the safety evaluation report.

Background information of interest in the review of the RTS is found in a number of SAR sections. A list of these is given in SRP Section 7.3 for reference purposes.

The GDC include requirements for the RTS. Review guidance for conformance to the GDC are provided in Appendix A of SRP Section 7.1 (Ref. 4). The review guidance includes references to the guidelines in regulatory guides and industry codes and standards where applicable. An audit review of the RTS should be made to confirm that the system conforms to the guidelines to support the conclusions of conformance to the regulations.

The review is to evaluate the protection system design against the requirements of IEEE Std. 279. This procedure is detailed in Appendix B to SRP Section 7.1 (Ref. 5). The procedures in Appendix B address only those design requirements that are specific in nature. For example paragraph 4.9 of IEEE Std 279 requires that the design include means for checking the availability of each system input sensor during operation. Appendix B outlines a straightforward procedure that can be used to determine whether or not this requirement is met.

Appendix B discusses the requirements of IEEE Std 279 and how they are used in the review of the RTS. Although the primary emphasis is on the equipment comprising the RTS, the reviewer should consider the protective functions on a systems level. It is necessary that the RTS design be compatible with the accident analysis. It is not sufficient to judge the adequacy of the RTS only on the basis of the design meeting the specific requirements of IEEE Std 279.

Major design considerations in the review of the RTS are as follows:

1. System Redundancy Requirements

   The review should confirm that the system redundancy requirements are satisfied. Generally, a minimum degree of redundancy of one satisfies RTS requirements. Most RTS parameters are monitored by four sensor channels with only two channels required to initiate the RTS logic channel protective action.

   Where it is determined that the spatial dependence of a parameter requires several sensor channels to assure core protection, the redundancy requirements are determined for the individual case. In certain designs adequate monitoring of core power requires a minimum number of sensors arranged in a given configuration to provide adequate protection. This aspect of redundancy is dealt with in coordination with the CPB to establish redundancy requirements.

   The redundancy requirements when considered strictly from an electrical point of view, is only necessary to assure that at least two redundant logic trains (minimum degree of redundancy of one) are provided to initiate reactor trip. From this standpoint the review may be reduced to a simple analysis in which redundant paths for sensors to logic and to actuation devices are identified to assure that the RTS functional requirements are met.

2. System Conformance with the Single Failure Criterion

In evaluating the adequacy of the RTS system in meeting the single failure criterion, both electrical and physical independence must be considered.

a. Electrical Independence

To assure electrical independence, the design bases governing the electrical independence of redundant sensors, logic elements, and actuation channels are required to satisfy Paragraph 4.6 of IEEE Std 279, which states that, "channels that provide signals for the same protection function shall be independent, and the likelihood of interaction between channels is considered," and the requirement of Paragraph 4.7.2. This paragraph requires that, "the transmission of signals from protection system channels that are used for other purposes (non-protective), such as control or readout and indication, are properly isolated to ensure that no credible failure at the output of an isolation device shall prevent the associated protective channel from meeting performance requirements." Examples of credible failures at the output of isolation devices are provided in Paragraph 4.7.2.

b. Physical Independence

To assure physical independence, the design bases governing the physical separation of redundant equipment including sensors, racks, panels, and control boards are evaluated in accordance with Regulatory Guide 1.75, "Physical Independence of Electric Systems." This regulatory guide sets forth guidelines for the physical separation of circuits and electrical equipment that is included in the RTS.

This review should determine whether the RTS is located in seismic Category I structures. In certain designs, RTS sensors may be located in non-seismic Category I structures such as the turbine building. For these special cases, the reviewer must assure that the most reasonable installation of sensors and circuits is provided in regard to physical protection against damage from a seismic event. Further guidance is provided by Branch Technical Position ICSB 15.

c. Single Failure Criterion

To assess the RTS acceptability with regard to the single failure criterion, IEEE Std 379 and Regulatory Guide 1.53 are used. Again, as was the case for redundancy requirements, review for compliance with the single failure criterion may be reduced to an analysis in which it is determined that the system can perform all protective functions concurrent with failure of any sensor, logic circuitry and components that meet the single failure criterion. IEEE Std 279, paragraph 4.2, provides an additional example of single failure criterion application.

With regard to power requirements, the RTS is required to assure that no failure of a power supply will result in maintaining power to the system such that the protective function (trip) of the RTS is

negated (fail-safe design). For example, loss of power to a sensor channel should cause a channel trip. Similarly, a loss of power to a logic element or actuator channel should result in a trip. Exception to this latter rule may be taken, as long as the single failure criterion is satisfied and the power sources required are designed as Class 1E power systems.

The RTS logic matrices should be reviewed to determine whether redundant circuitry includes the contacts of relays or switches in mutually redundant logic ciruits. This task can be accomplished during the detailed drawing review. When violations of the single failure criterion are found, they are to be identified to the applicant and corrected. The staff safety evaluation report should discuss the final disposition of designs that are revised to satisfy the acceptance criterion.

3. System Testing and Inoperable Surveillance

The descriptive information as supplemented by functional logic diagrams (CP and OL) and electrical schematics (OL) are reviewed to verify that the design has the necessary provisions to permit testing of the RTS on a periodic basis when the reactor is in operation. The reviewer is guided by the recommendations set forth in Regulatory Guide 1.22 and IEEE Std 279, paragraph 4.10, in arriving at an acceptable method of periodic testing of actuation devices (e.g., solenoids, breakers) and actuated equipment (control rods). The same guidance is used to review testability of all modules, relays, permissives, bypasses, and control devices.

The descriptive information (CP and OL) and the design implementation as depicted on electrical drawings (OL) of the means proposed for automatically indicating, at the system level, bypassed or deliberately inoperable RTS protection channels are reviewed to ascertain that the design is consistent with Regulatory Guide 1.47 as supplemented by Branch Technical Position ICSB 21 and with IEEE Std 279, paragraph 4.13.

An important part of the review is the engineering design review at the OL stage. The drawing review should confirm that the design and layout meet the applicable criteria listed under subsection II.

A site visit should be performed before the evaluation findings are written for an OL. A site visit should include an audit verification that the design and layout criteria reviewed during the drawing review are implemented. An outline of topics for a site visit is provided in Appendix 7-B (Ref. 6) to SRP Chapter 7.

In certain instances, it will be the reviewer's judgment that for a specific case under review, emphasis should be placed on specific aspects of the design, while other aspects of the design need not receive the same emphasis and in-depth review. Typical reasons for such a non-uniform placement of emphasis are the introduction of new design features or the utilization in the design of design features previously reviewed and found acceptable. However, in all cases, the review must be sufficient to conclude conformance to the acceptance criteria, i.e., the requirements of the Commission's regulations.

IV. EVALUATION FINDINGS

The reviewer verifies that sufficient information has been provided and that his review supports conclusions of the following type, to be included in the staff's safety evaluation report:

The staff concludes that the design of the reactor trip system (RTS) and the design of the EAS system are acceptable and meet the relevant requirements of General Design Criteria 2, 4, 20, 21, 22, 23, 24, and 25 and 10 CFR Part 50, §50.55a(h):

We have conducted an audit review of these systems for conformance to guidelines of the regulatory guides and industry codes and standards applicable to these systems. In Section 7.1 of this SER we concluded that the applicant had adequately identified the guidelines applicable to these systems. Based upon our audit review of the system design for conformance to the guidelines we find that there is reasonable assurance that systems conform fully to the guidelines applicable to these systems.

Our review has included the identification of those systems and components for the RTS which are designed to survive the effects of earthquakes, other natural phenomena, abnormal environments and missiles. Based upon our review we conclude that the applicant has identified those systems and components consistent with the design bases for those systems. Sections 3.10 and 3.11 of this SER address the qualification programs to demonstrate the capability of these systems and components to survive these events. Therefore we find that the identification of these systems and components satisfies this aspect of the GDC 2 and 4.

Based on our review we conclude that the RTS conforms to the design bases requirements of IEEE Std 279 and that the system includes the provision to sense accident conditions and anticipated operational occurrences to initiate reactor shutdown consistent with the accident analysis presented in Chapter 15 of the SAR. Therefore, we find that the RTS satisfies the requirements of GDC 20.

The RTS conforms to the guidelines for periodic testing in Regulatory Guide (R.G.) 1.22 and IEEE Std 338 as supplemented by R.G. 1.118. The bypassed and inoperable status indication conforms to the guidelines of R.G. 1.47. The RTS conforms to the guidelines on the application of the single failure criterion in IEEE Std 379 as supplemented by R.G. 1.53. Based on our review we conclude that the RTS satisfies the requirement of IEEE Std 279 with regards to the system reliability and testability. Therefore we find that the RTS satisfies the requirement of GDC 21.

The RTS conforms to the guidelines in IEEE Std 384 as supplemented by R.G. 1.75 for the protection system independence. Based on our review we conclude that the RTS satisfies the requirement of IEEE Std 279 with regards to the systems independence. Therefore, we find that the RTS satisfies the requirement of GDC 22.

Based on our review of the failure modes and effects analysis for the RTS we conclude that the system is designed to fail into a safe mode if conditions such as disconnection of the system, loss of energy, postulated adverse environment are experienced. Therefore, we find that the RTS satisfies the requirements of GDC 23.

Based on our review of the interfaces between the RTS and plant operating control systems we conclude that the system satisfies the requirements of IEEE Std 279 with regards to control and protection system interactions.

Our conclusions noted above are based upon the requirements of IEEE Std 279 with respect to the design of the RTS. Therefore, we find that the RTS satisfies the requirement of 10 CFR Part 50, §50.55a(h) with regards to IEEE Std 279.

-OR-

The RTS is completely independent of any plant operating control system.

-AND-

Therefore, we find that the RTS satisfies the requirement of GDC 24.

Based on our review of the reactor protection system, we conclude that the system satisfies the protection system requirements for malfunctions of the reactivity control system such as accidental withdrawal of control rods. Section 15 of the SAR addresses the capability of the system to assure that fuel design limits are not exceeded for such events. Therefore we find that the RTS satisfies the requirements of GDC 25.

Our review of the RTS has examined the dependence of this system on the availability of essential auxiliary support (EAS) systems. Based on our review and coordination with those having primary review responsibility of the EAS systems, we conclude that the design of the RTS is compatible with the functional performance requirements of EAS systems.

The applicant has also incorporated in the system design the recommendations of Task Action Plan items [identify item number and how implemented] which we have reviewed and found acceptable.

The conclusion noted above for the RTS is applicable to all portions of the systems except for the following for which acceptance is based upon prior Commission review and approval as noted. [List applicable system or topics and identify references].

V. IMPLEMENTATION

The following is intended to provide guidance to applicants and licensees regarding the NRC staff's plans for using this SRP section.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used by the staff in its evaluation of conformance with Commission regulations.

Implementation schedules for conformance to parts of the method discussed herein are contained in the referenced regulatory guides and NUREGs.

VI. REFERENCES

1. Standard Review Plan Section 7.1, Table 7-1, "Acceptance Criteria and Guidelines for Instrumentation and Control Systems Important to Safety."

2. Standard Review Plan Appendix 7-A, "Branch Technical Positions (ICSB)."

3. Standard Review Plan Section 7.1, Table 7-2, "TMI Action Plan Requirements for Instrumentation and Control Systems Important to Safety."

4. Standard Review Plan Section 7.1, Appendix A, "Acceptance Criteria and Guidelines for Instrumentation and Control Systems Important to Safety."

5. Standard Review Plan Section 7.1, Appendix B, "Guidance for Evaluation of Conformance to IEEE Std 279."

6. Standard Review Plan Appendix 7-B, "General Agenda, Station Site Visits."

APPENDIX A
STANDARD REVIEW PLAN SECTION 7.2
USE OF IEEE STD 279 IN THE REVIEW OF THE RTS

(Appendix A to SRP Section 7.2 has been superseded by Appendix B to SRP Section 7.1)